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Research Article



Application of the sub-index model for valuation water quality for irrigation uses: A case study of groundwater in Al-Rashidiya area, North of Mosul city of Iraq

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Abstract

In the current study, wells water were assessed in Al-Rashidiya area located north of the left side of Mosul for irrigation, which is characterized by its agricultural nature and the abundance of fields and farms in it, was evaluated, One hundred water samples were taken from ten wells throughout the period from (October 2019 to mid-January 2020) to estimate some characteristics Physiochemical such as ph, Ec, and some negative and positive ions and irrigation parameters such as (SAR), (% Na), (RSC), (MH), (PS), (KR) and (PI), and the mathematical model was applied using eleven parameters to calculate IWQI values. The results of the IWQI values indicated that the water quality of the wells was of an excellent category for irrigation, as the values ranged between (23,582 to 30,429). This improvement in quality is due to the fact that most of the studied parameters did not exceed the permissible confines for irrigation.

Keywords: Wells water of Al-Rashidiya area, IWQI, Water quality for irrigation

Introduction

The problem of environmental pollution, including water pollution, is today among the most important and sensitive issues in the world, so it was necessary to deal with it with the utmost seriousness because this problem is related to the existence of man, his health and his economy (Al-Shanona et al, 2018). The interest in securing and managing water resources is one of the basic pillars of national and national security, especially in arid and semi-arid regions, as well as countries whose water sources are from outside their borders, such as Iraq, and that one of the most important challenges facing Iraq, especially in recent years, is to achieve self-sufficiency in water resources that are a threat He has, in addition to other threats, such as climatic conditions, and countries that originate water sources from their lands trying to control, and exploit them politically and economically to achieve their goals. Upstream countries and resolving economically and politically outstanding problems, as well as urging for efficient management of Iraqi water resources by

building service and scientific institutions and developing scientific and practical plans to solve problems related to water resource pollution and rationalizing water consumption (Bortolini et al, 2018; Al-Sardar and Saffawi, 2019). The lack of water is an increasingly important problem facing Iraq, As a result of the low levels from the Rivers of Tigris and Euphrates and most of the Iraqi tributaries, along with increasing salinity problems. Studies and reports indicate that Iraq may be exposed to serious water crises. Consequently, the main problem should not be left aside and interested in proposing non-economic projects and their results are negative for the country. Instead, scientific and practical solutions must be devised to address or mitigate the water scarcity crisis, which can be solved and by working hard with willpower and avoiding compliments in the implementation and enforcement of laws and because the water problem is mainly internal, there are some possible solutions that (Al-Hamdany et al., 2018: Al-Saffawi, 2018a)

1. Rationing water consumption as traditional irrigation methods change.
2. Using the main principles of integrated and comprehensive management of water resources.
3. Constructing small dams on the flowing seasonal valleys to harvest and store rainwater, which has proven successful in many countries of the world.

Material and Methods

Description of the study area

The study area located on the left side of the city of Mosul and northwest of Nineveh governorate and it is called Al-Rashidiya. The residents of the region are interested in agriculture and livestock breeding, where fields and farms are spread in the study area. So, ten wells were randomly chosen from the studied area and these wells are of surface type wells because their depths did not exceed twenty meters (Al-Hamdany et al., 2020a).

Table (1): Coordinates and characteristics of the studied wells.

Wells	E	N	Altitude (m)	Depth (m)
1	43° 05' 50"	36° 24' 10"	228	6.0
2	43° 05' 43"	36° 24' 01"	227	7.0
3	43° 05' 52"	36° 23' 94"	225	10
4	43° 05' 12"	36° 24' 01"	225	10
5	43° 05' 68"	36° 23' 91"	226	7.0
6	43° 05' 74"	36° 24' 01"	224	8.0
7	43° 05' 72"	36° 23' 91"	225	10
8	43° 05' 79"	36° 23' 97"	224	12
9	43° 10' 16"	36° 40' 52"	224	10
10	43° 06' 12"	36° 23' 92"	222	4.0



Fig 1: A map of the Al-Rashidiya area showing the sites of studied wells.

Geology of the study area

Nineveh Governorate is characterized by the widespread formation of plashi containing limestone CaCO₃ and marl and Al-Fa'tha formation (middle myosin) that consists of limestone, salty rocks, gypsum (CaSO₄.2H₂O), anhydrite (CaSO₄) and marl, and this composition is spread in The northern parts of Iraq and the formation of Anjana (Upper Miocene) which consists of a succession of mud, sandstone, and marl, and these formations affect the quality of the water that passes through it (Al-Saffawi and Al-Shuuchi, 2018; Al-Youzbaky et al., 2018).

Methodology

In the current study, 100 water samples were collected from ten randomly distributed wells in the region (from October 2019 to mid-January 2020), using polyethene bottles that were cleaned. It washed with distilled water and sampled water before filling (APHA, 1998). The well sites were loaded using the GPS for Google Earth and Fig. (1) shows the locations of the wells under study and table (1) showing the latitude, longitude, depth and Altitude of the studied wells. Analyzes of water samples were performed in the laboratories of the Department of Biology, College of Education for Pure Sciences, University of Mosul, to measure pH, electrical conductivity, calcium, magnesium, sodium, potassium ions, chlorides, sulfates and bicarbonate according to international standard methods (APHA, 1998, 2017), and the irrigation water criteria were calculated as such sodium adsorption ratio (SAR), (%Na), (RSC), (MH), (PS), (KR) and (PI) as from the following equations (Bhat et al, 2018; Al-Saffawi et al, 2019a; Yasmin et al, 2019; Xu et al, 2019; Al-Saffawi et al, 2020a):

$$SSP = (Na + K) \times 100 / (Ca + Mg + Na + K)$$

$$SAR = [Na] / \{ (Ca + Mg) / 2 \}^{1/2}$$

$$PI = [Na + (HCO_3)^{1/2}] \times 100 / (Ca + Mg + Na)$$

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

$$1/2 SO_4 + Cl = PS$$

$$KR = Na / (Ca + Mg)$$

Where units are used with the meq. l-1.

The quality of water used for irrigation was evaluated using internationally approved classifications such as the American Salinity Laboratory classification USDA and Donnen's classification referred to (Nag, and Das, 2014) for the combined effect of the concentration of chloride ions, sulfates, etc., the water quality index was (WQI) applied using eleven criteria: pH Ec, HCO₃, Cl, KI, PI, % Na, MH, RSC, SAR, PS. which was calculated using the following equation (Shobha, 2018; Al-Saffawi et al, 2020b; Chebet et al, 2020):

$$K = 1 / \sum_{i=1}^n \frac{1}{S_{pH}} + \frac{1}{S_{Ec}} + \dots \dots \dots (1)$$

$$W_n = K / S_i \dots \dots \dots (2)$$

$$q_i = 100 \times [V_n - V_i] / [S_i - V_i] \dots \dots \dots (3)$$

$$WQI = \sum Qi \times Wn / \sum Wn \dots\dots\dots(4)$$

Where:

K: the proportionality constant., Wn weight value for each property., Si: allowable standard concentration as shown in the table (2)., qi: quality rating of each parameter., Vn: measured value., Vi: ideal values Its equal to zero for all parameters except pH values equal to 7.0 ., WQI: Water Quality Index.

Table (2): Permissible limits(Si) and relative weight (Wn) values for studied irrigation parameters.

Parameters	Standard limit (Si)	Values of (Wn)
pH	6.5-7.5	0.076923000
Ec	2000	0.000250000
Cl	10	0.050000000
HCO ₃	8.5	0.058823500
SAR	18	0.027777777
RSC	2.25	0.222222222
MH	50	0.010000000
%Na	60	0.008333333
PS	10	0.050000000
KR	1	0.500000000
PI	75	0.006666666
Σ		1.010996000

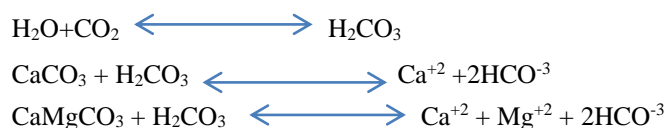
After finding IWQI values, they are classified into five categories: Excellent Quality water (IWQI 0-25), good (IWQI 26-50), poor (IWQI 51-75), very poor (IWQI 76-100) and inadequate quality (IWQI >100) (KOÇ, 2018; Issa and Alrawi, 2018).

Results & Discussions

The electrical conductivity expresses the quantity and quality of ions dissolved in water (APHA, 2017), and the results shown in Table (3) indicate that the values fluctuated between (1040 - 3712) μS. cm-1, and these differences are By the character of the geological formations through which the water passes, because the groundwater passing through the layers rich in evaporation salts is characterized by high salts values in them (Al-Hamdany, et al, 2020b). These values are less than the values obtained by Al-Saffawi (2019) in its study of water wells of the Al-Nimrud region at southeastern of Mosul city of Mosul city, which did reach to (5110) μS. m-1. The pH is an indicator of the amount of balance between acidity and water alkalinity. Groundwater values are affected by the nature and dissolution of salt and oxides in the ground rocks (Al-Saffawi and Al-Shuuchi, 2018). It is noted from the table 4 that the fluctuation in pH values, which ranged between (6.70 to 7.59), this is due to the ability of the Acid Neutralization Capacity (ANC) for Iraqi water and soil rich in bicarbonate and carbonate salts (Al-Saffawi and Talat, 2019). As for the relative decrease in values, it may be due to the presence of acid ions such as sulfates, nitrates and chlorides, and the occurrence of processes of decomposition and anaerobic biological oxidation of organic materials, which leads to the

formation of many acidic compounds and carboxylic acids (Al-Saffawi, 2019).

This confirms the high concentrations of ions rates bicarbonates to reach (8.24 ± 1.02) meq. l-1 at the well No. 5, and this rise is due to the dissolution of CO₂ in rain water to form carbonic acid, which running to the geological layers containing dolomite rocks (Ca.MgCO₃.nH₂O) and limestone (CaCO₃.nH₂O) and interact with them to produce bicarbonates compounds as in the following equations: (Al-Saffawi and Al-Sardar, 2018)



For the same reasons for rising concentrations of calcium and magnesium ions to reach their averages to (30.5 ± 7.84) and (20.3 ± 7.23) meq. l-1 on the sequence. Thus, it reflected on the magnesium hazard (MH) values, with rates ranging between (40 to 51), however, 90% Samples are within allowable irrigation limits. Also, it is observed from the tables (3, 4) the fluctuation of sodium and potassium ions concentration , which ranged between (2.90 to 8.5) and (0.2 to 1.4) meq. l-1 consecutively. This rise in calcium and magnesium concentrations compared to the bicarbonate, sodium and magnesium ions led to a decrease in the values of each of the (RSC), (%Na), (SAR), (KR) and (PI), as it reached rates to (0.0, % 12.2, 1.28 0.22 and 21.9) on the sequence, which is within the permissible boundaries for irrigation (Moghimi, 2016). As for the values of P. Salinity, it is noticed from the tables (3, 4) that their levels rise to ranges between (15.7 to 25.6) meq. l-1, thus the studied water is poor quality for irrigation of all types of soils according to the Doneen classification (Kablan, 2018). This deterioration in the quality of the water is due to the high chloride content and sulfates ions as a result of the presence of salt rocks, gypsum and anhydrite in the geological formations of the study area (Al-Hamdany et al, 2020a; Al-Saffawi et al 2020a) where the concentrations reached (13.4 and 46.1) meq. l-1 consecutively.

Water Quality Assessment for Irrigation

Interpreting test results for irrigation water is not always an easy task. In most cases, among a large number of parameters used to describe the state of water quality for any water resource, there are some parameters within the permissible limits for irrigation, but others are not, and the overall quality of water is often vague. Therefore, modern methods such as water quality indicators (WQI) were used. It is a mathematical model that is used to convert large water quality data to a single number, representing interferences between all parameters used in the model, which facilitate the judgment on water quality. The water quality index results for the irrigation (IWQI) as shown in table (5) indicate that all studied well water was from the category of excellent quality irrigation water, where the values ranged between (23.582 to 30.429) and this is due to the fact that most of the studied parameters were within the permissible limits for irrigation as previously described .

Table 3: The extent, rate and standard deviation of the well water results in Al-Rashidiya area, Nineveh Governorate, Iraq.

Wells paramet.		1	2	3	4	5	6	7	8	9	10
pH	min	6.70	6.87	6.86	6.84	6.92	7.00	6.97	6.91	6.91	6.46
	max	7.04	7.13	7.13	7.50	7.10	7.23	7.59	7.58	7.35	7.22
	mean	6.88	6.96	6.97	7.02	7.01	7.13	7.28	7.11	7.12	6.97
	Sd±	0.10	0.09	0.08	0.18	0.06	0.07	0.22	0.23	0.13	0.10
EC $\mu S.m$	min	2250	2146	2057	2240	2530	2681	2611	1040	2611	2680
	max	2989	2622	3359	2613	2909	3510	3063	3712	3480	3380
	mean	2769	2385	3061	2419	2721	3006	2812	2874	2921	3070
	Sd±	216	171	392	127	140	256	155	973	275	215
Cl meq/l	min	3.70	3.20	7.40	4.30	4.10	5.30	5.40	2.00	4.40	5.10
	max	6.30	6.00	11.1	9.00	5.40	7.30	7.00	13.4	10.5	8.40
	mean	5.40	5.00	10.0	5.60	5.00	6.50	6.20	8.80	6.30	7.10
	Sd±	0.78	0.84	1.19	1.26	0.37	0.66	0.42	4.01	1.72	1.09
HCO ₃ meq/l	min	6.70	6.40	6.30	7.30	7.20	6.10	7.50	3.00	5.50	6.00
	max	9.50	9.20	9.90	10.8	10.1	10.0	10.5	10.0	9.50	8.70
	mean	7.17	7.25	7.53	8.15	8.24	7.56	8.34	6.47	7.10	6.83
	Sd±	0.83	0.97	0.95	1.02	1.02	0.99	0.87	2.19	1.28	0.79
SO ₄ meq/l	min	20.1	15.0	12.6	14.0	17.2	16.4	20.2	8.4	16.3	19.0
	max	37.4	27.3	44.2	26.0	33.0	36.0	39.0	43.0	40.0	46.1
	mean	24.7	22.0	30.4	19.9	24.6	27.9	26.9	26.9	26.9	31.4
	Sd±	5.19	4.30	8.48	4.07	5.11	6.45	6.76	11.74	6.57	8.09
Ca meq/l	min	24.4	15.6	23.6	14.4	17.2	20.0	12.4	5.0	12.8	18.0
	max	35.2	23.1	49.0	21.0	33.2	37.2	38.7	51.2	52.3	32.5
	mean	27.1	18.5	30.5	17.2	23.8	26.6	21.6	25.3	25.6	25.5
	Sd±	3.18	2.59	7.84	2.46	5.64	4.63	7.59	16.85	11.62	4.78
Mg meq/l	min	15.0	11.2	4.8	3.6	6.8	6.0	6.3	2.4	12.0	8.4
	max	25.2	20.0	27.0	16.4	25.2	25.2	30.0	49.6	34.8	30.0
	mean	18.6	15.1	20.3	13.1	17.7	18.0	21.9	21.1	18.6	19.9
	Sd±	3.17	2.94	7.23	4.36	6.15	6.57	6.78	13.60	6.44	7.94
Na meq/l	min	3.10	2.90	4.10	3.00	3.00	3.60	3.40	3.40	3.30	3.80
	max	7.20	7.00	8.10	6.10	6.60	8.00	7.00	8.50	7.20	8.30
	mean	5.15	4.85	6.34	4.69	4.89	5.54	5.34	5.72	5.41	6.10
	Sd±	1.55	1.60	1.73	1.33	1.46	1.66	1.56	1.84	1.67	1.97
K meq/l	min	0.40	0.60	0.50	1.10	0.20	0.30	0.20	0.200.50	0.20	0.20
	max	1.00	1.30	1.10	1.80	0.60	0.80	0.50	0.38	1.40	0.60
	mean	0.72	0.99	0.78	1.39	0.39	0.56	0.38	0.14	0.54	0.33
	Sd±	0.22	0.28	0.19	0.21	0.15	0.21	0.15	0.38	0.38	0.13

Conclusions & Recommendations

1. The studied water was characterized by the relative height of some studied parameters and for some periods such as electrical conductivity and latent salinity P. Salinity, calcium ions, magnesium sulfate, bicarbonate.

2. Because of the overlaps between these parameters, although most of them are within the upper limits allowed for irrigation; As 100% of the IWQI values were of good quality for irrigation.

Therefore, we recommend conducting periodic tests of resources with emphasis on using mathematical models to find

the IWQI values because knowing these values for any water resource will help water officials and policymakers explain the groundwater quality conditions to take appropriate action.

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Table 4: the extent, rate and standard deviation of the well water results in Al-Rashidiya area, Nineveh Governorate, Iraq

Wells Paramet.		1	2	3	4	5	6	7	8	9	10
SAR	min	0.70	0.70	0.80	0.80	0.70	0.80	0.80	0.80	0.60	0.80
	max	1.50	1.60	1.60	1.50	1.40	1.80	1.50	2.00	1.60	1.90
	mean	1.08	1.17	1.27	1.21	1.06	1.19	1.13	1.24	1.16	1.28
	Sd±	0.30	0.37	0.33	0.28	0.28	0.36	0.28	0.37	0.36	0.36
RSC	min	-45.0	-3.01	-49.0	-26.0	-39.0	-45.0	-42.0	-60.0	-58.0	-47.0
	max	-9.20	-2.00	-38.0	-11.0	-18.0	-23.0	-22.0	-12.0	-24.0	-26.0
	mean	-36.0	-26.0	-43.0	-22.0	-33.0	-37.0	-35.0	-40.0	-37.0	-39.0
	Sd±	10.0	3.23	3.52	5.03	6.42	7.13	6.19	15.8	9.08	7.42
MH	min	30.0	34.0	8.90	20.0	25.0	20.0	14.0	5.00	22.0	26.0
	max	48.0	53.0	52.0	53.0	57.0	50.0	71.0	74.0	73.0	61.0
	mean	41.0	45.0	40.0	42.0	42.0	40.0	51.0	49.0	44.0	43.0
	Sd±	5.30	5.80	14.1	10.3	11.8	11.1	14.6	25.0	15.7	13.1
%Na	min	7.0	8.0	7.6	8.6	6.9	7.3	7.6	7.0	5.2	7.3
	max	13.0	15.0	13.3	15.5	13.0	18.8	14.1	19.1	15.0	19.0
	mean	9.84	12.2	10.9	12.9	10.5	11.0	10.7	12.2	11.1	11.9
	Sd±	2.24	2.75	2.38	2.35	2.10	3.47	2.07	4.36	3.20	3.21
PS	min	14.2	14.2	15.0	11.8	12.7	13.5	16.1	6.2	14.2	15.9
	max	24.0	19.1	33.1	20.0	22.5	32.2	26.5	34.5	25.0	31.3
	mean	17.8	16.5	25.6	15.7	17.5	21.4	20.2	22.9	19.8	23.1
	Sd±	2.70	1.56	4.65	2.73	2.97	5.18	3.51	9.96	3.20	4.78
KR	min	0.08	0.09	0.08	0.09	0.07	0.07	0.08	0.07	0.05	0.08
	max	0.15	0.96	0.16	0.19	0.15	0.23	0.16	0.24	0.18	0.24
	mean	0.12	0.22	0.12	0.15	0.11	0.12	0.12	0.14	0.12	0.13
	Sd±	0.02	0.26	0.03	0.04	0.03	0.05	0.03	0.06	0.05	0.05
PI	min	13.0	16.1	13.0	17.0	12.8	12.4	14.2	10.4	10.0	12.0
	max	18.1	22.1	18.2	27.0	20.4	26.4	20.0	28.0	20.4	25.0
	mean	15.3	19.5	15.9	21.9	16.9	16.8	17.0	17.8	16.7	17.1
	Sd±	1.89	2.12	2.11	2.82	2.21	3.91	1.90	5.90	3.20	3.40

Table 5: Weight value(Wn) , quality rating (qi) of each parameter and water quality Index (WQI)

Wells	Paramet.	1	2	3	4	5	6	7	8	9	10
pH	qn	24.000	8.0000	8.0000	4.0000	2.0000	26.000	56.000	22.000	24.000	6.0000
	qn×Wn	1.8456	0.6152	0.6152	0.3076	0.1538	1.9994	4.3064	1.6918	1.8456	0.4614
EC	qn	139.00	119.00	153.00	121.00	136.00	150.00	141.00	144.00	146.00	154.00
	qn×Wn	0.0417	0.0357	0.0459	0.0363	0.0408	0.045	0.0423	0.0432	0.0438	0.0462
Cl	qn	54.000	50.000	100.00	56.000	50.000	65.000	62.000	88.000	63.000	71.000
	qn×Wn	2.7000	2.5000	5.0000	2.8000	2.5000	3.2500	3.1000	4.4000	3.1500	3.5500
HCO ₃	qn	000.84	85.000	89.000	96.000	97.000	89.000	98.000	76.000	84.000	80.000
	qn×Wn	4.9392	4.9980	5.2332	5.6448	5.7036	5.2332	5.7624	4.4688	4.9392	4.704
SAR	qn	6.0000	6.5000	7.1000	6.7000	5.9000	6.6000	6.3000	6.9000	6.4000	7.1000
	qn×Wn	0.1668	0.1807	0.1974	0.1863	0.1640	0.1835	0.1751	0.1918	0.1779	0.1974
RSC	qn	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	qn×Wn	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MH	qn	81.500	90.000	80.200	84.000	84.400	79.000	102.00	98.400	87.200	85.300
	qn×Wn	0.8150	0.9000	0.8020	0.8400	0.8440	0.7900	1.0200	0.9840	0.8720	0.8530
%Na	qn	16.400	20.300	18.100	21.500	17.500	18.400	18.000	20.400	18.500	20.000
	qn×Wn	0.1361	0.1685	0.1502	0.1785	0.1453	0.1527	0.1494	0.1693	0.1536	0.166
P.S	qn	178.30	165.30	256.00	157.00	175.00	214.30	202.10	228.50	198.00	231.40
	qn×Wn	8.9150	8.2650	12.800	7.8500	8.7500	10.715	10.105	11.425	9.9000	11.570

KR	qn	11.600	22.300	12.100	14.900	11.200	12.300	11.600	13.800	11.900	13.100
	qn×Wn	5.8000	11.150	6.0500	7.4500	5.6000	6.1500	5.8000	6.9000	5.9500	6.5500
PI	qn	20.400	26.000	21.200	29.200	22.500	22.400	22.600	23.700	22.300	22.800
	qn×Wn	0.1367	0.1742	0.1420	0.1956	0.1508	0.1501	0.1514	0.1588	0.1494	0.1528
Σ qn × Wn		25.496	28.987	31.036	25.489	24.052	28.669	30.612	30.433	27.182	28.251
WQI		24.997	28.420	30.429	24.990	23.582	28.108	30.013	29.837	26.650	27.698
Wat. Quality		Excell.	Excell.	Excell.	Excell.	Excell	Excell	Excell	Excell	Excell	Excell

Conflict of Interest

Authors hereby declare no conflict of interest.

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